Next Generation Transport Concepts and Enabling Technology Research at NASA

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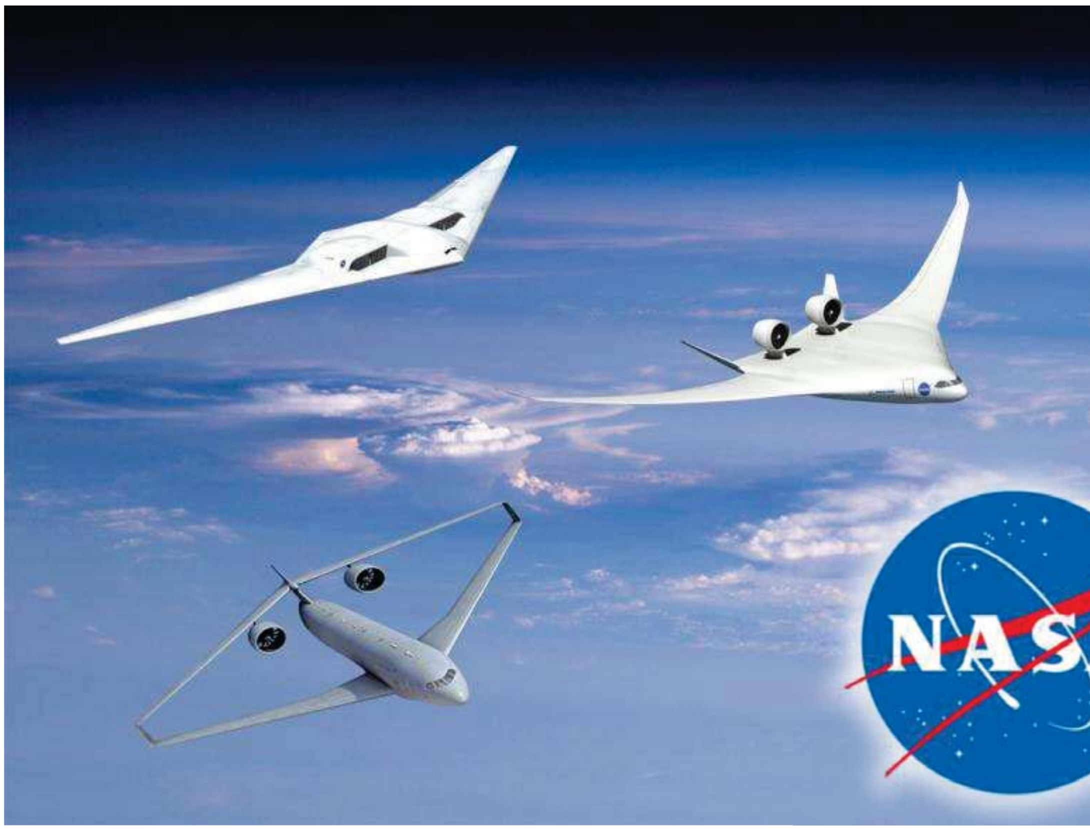
8 November, 2013



Agenda

- Introduction / Background
- Advanced Aircraft Concepts
- Subsystem Concepts and Enabling Technologies
- My little piece: Peak-seeking control

NASA Mission Directorates

Science
Mission Directorate
(SMD)

Aeronautics Research
Mission Directorate
(ARMD)

Human Exploration &
Operations Mission
Directorate
(HEOMD)

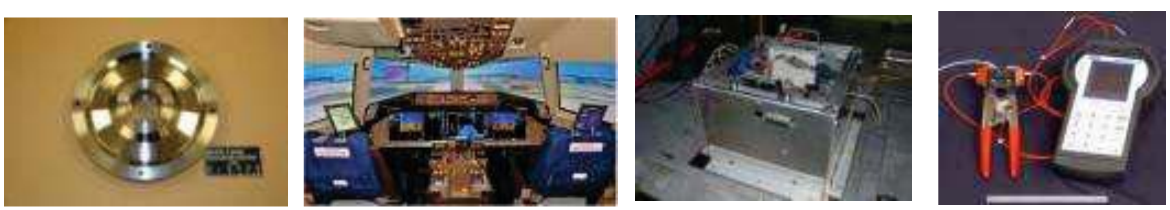
Space Technology
Mission Directorate
(STMD)

NASA Aeronautics Programs

Fundamental Aeronautics

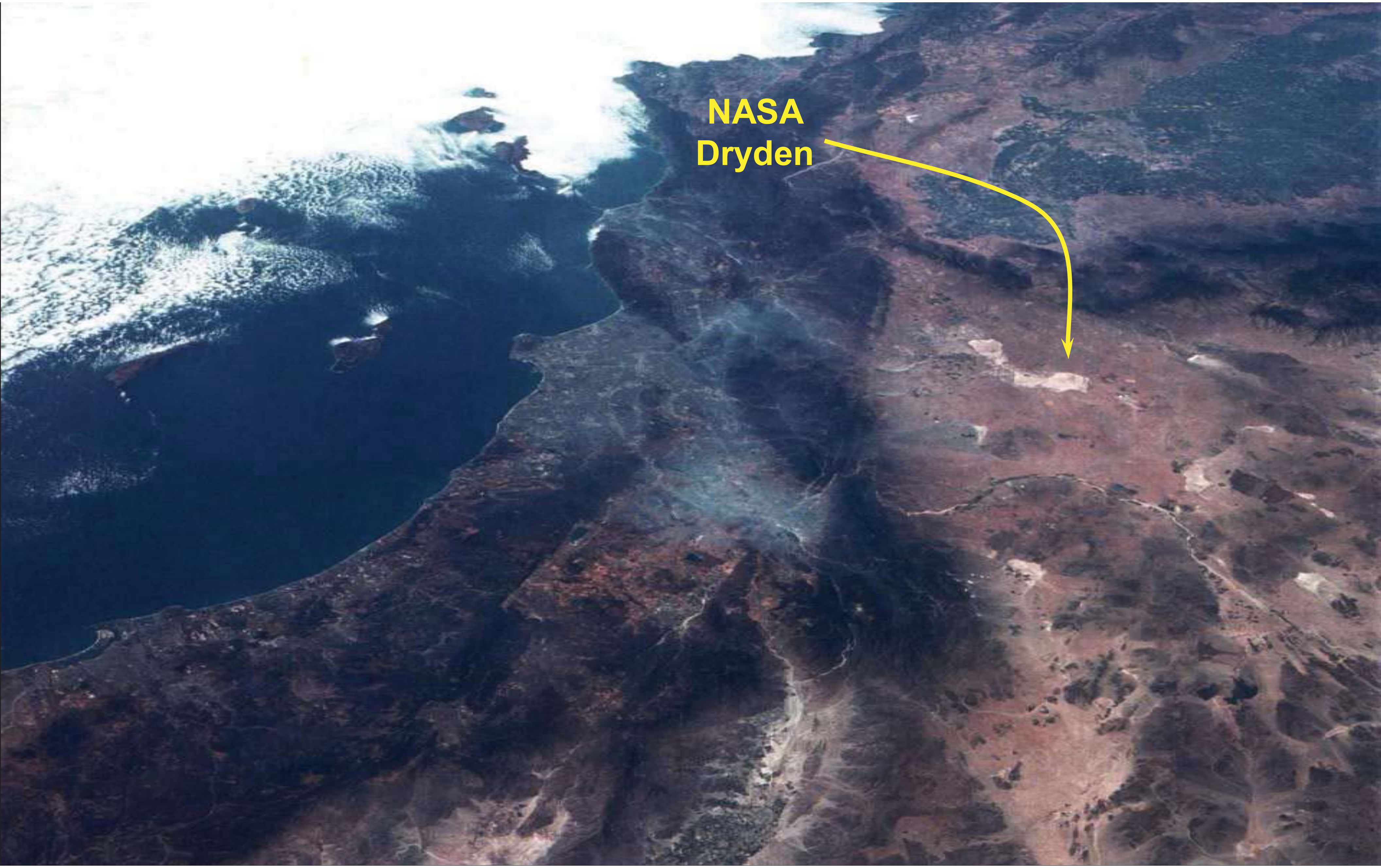
Airspace Systems

Integrated Systems Research



Aviation Safety

Aeronautics Test

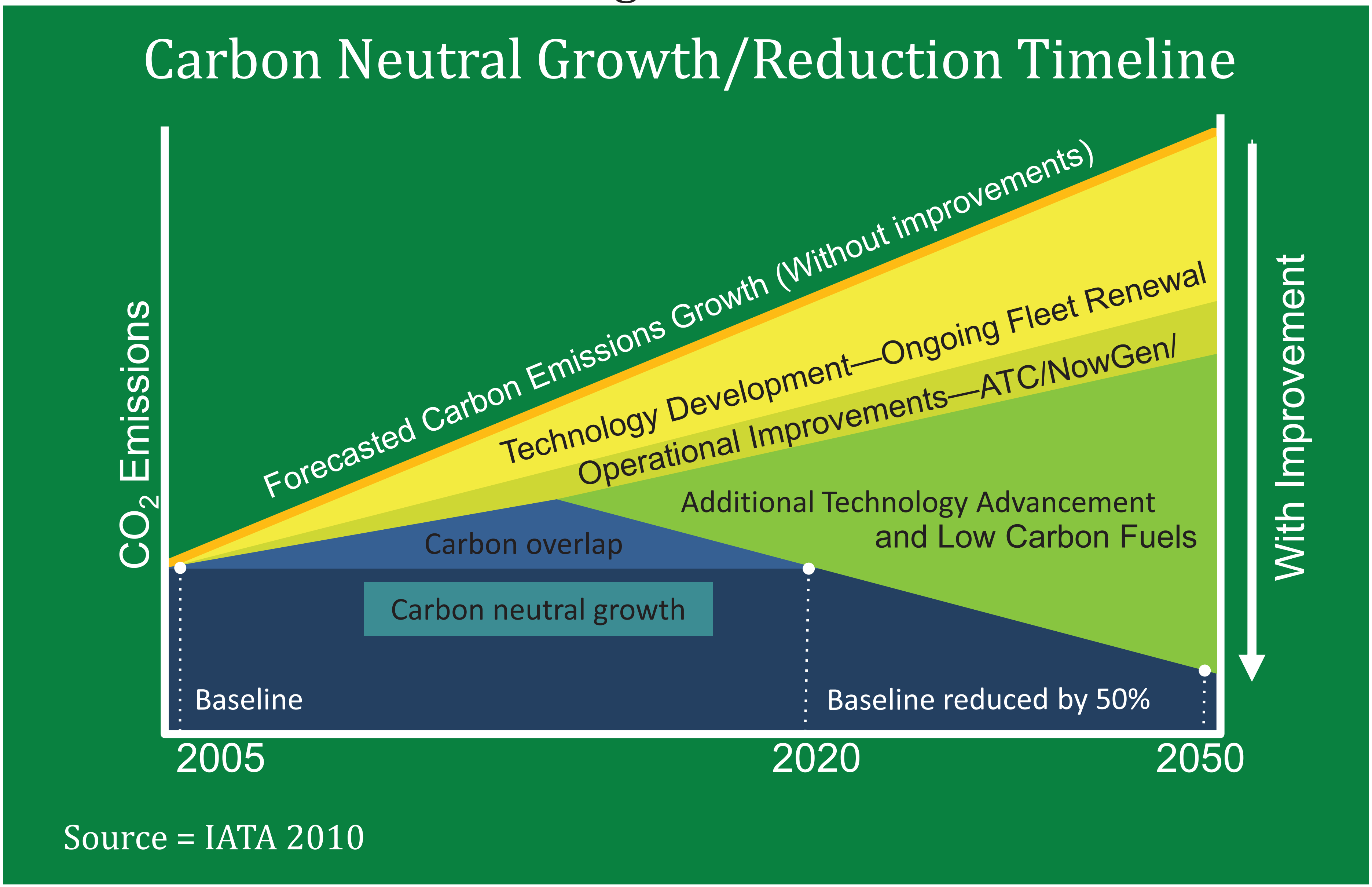

NASA
Dryden

The need for flight research:

"... to separate the real from the imagined and to make known the overlooked and the unexpected..."

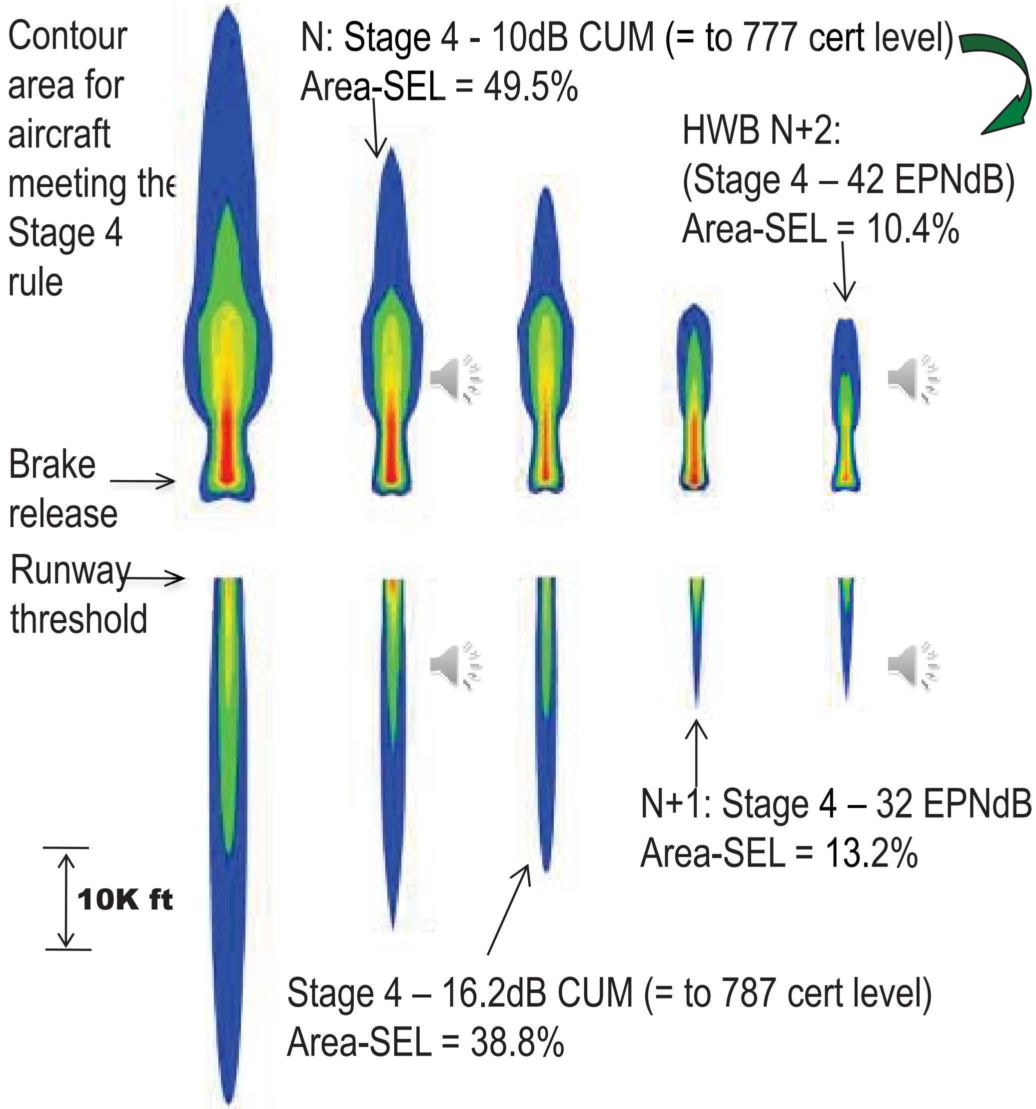
Dr. Hugh L. Dryden
first Deputy Administrator of NASA

Aviation's Grand Challenge 1: Reduce Carbon Emissions



Aviation Grand Challenge 2: Contain noise within airport boundary

Change in noise "footprint" area (within 85 dB) **for a landing and takeoff**



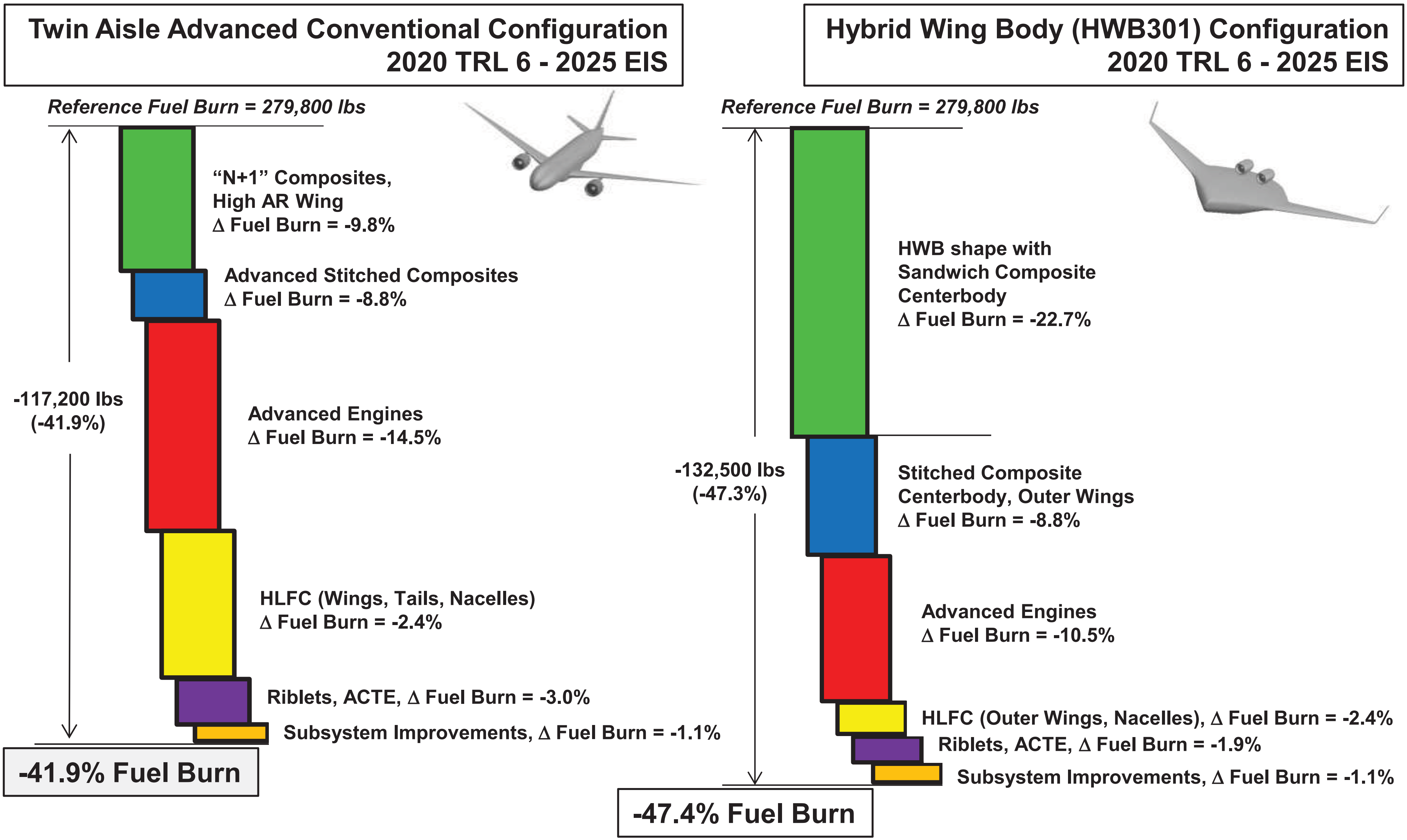
80% Reduction in Noise Footprint Area

Thomas, R.H., Burley, C.L, and Olson, E.D., "Hybrid Wing Body Aircraft System Noise Assessment with Propulsion Aircraft Aeroacoustic Experiments," ***International Journal of Aeroacoustics*****, Vol 11 (3+4), pp.369-410, 2012.**

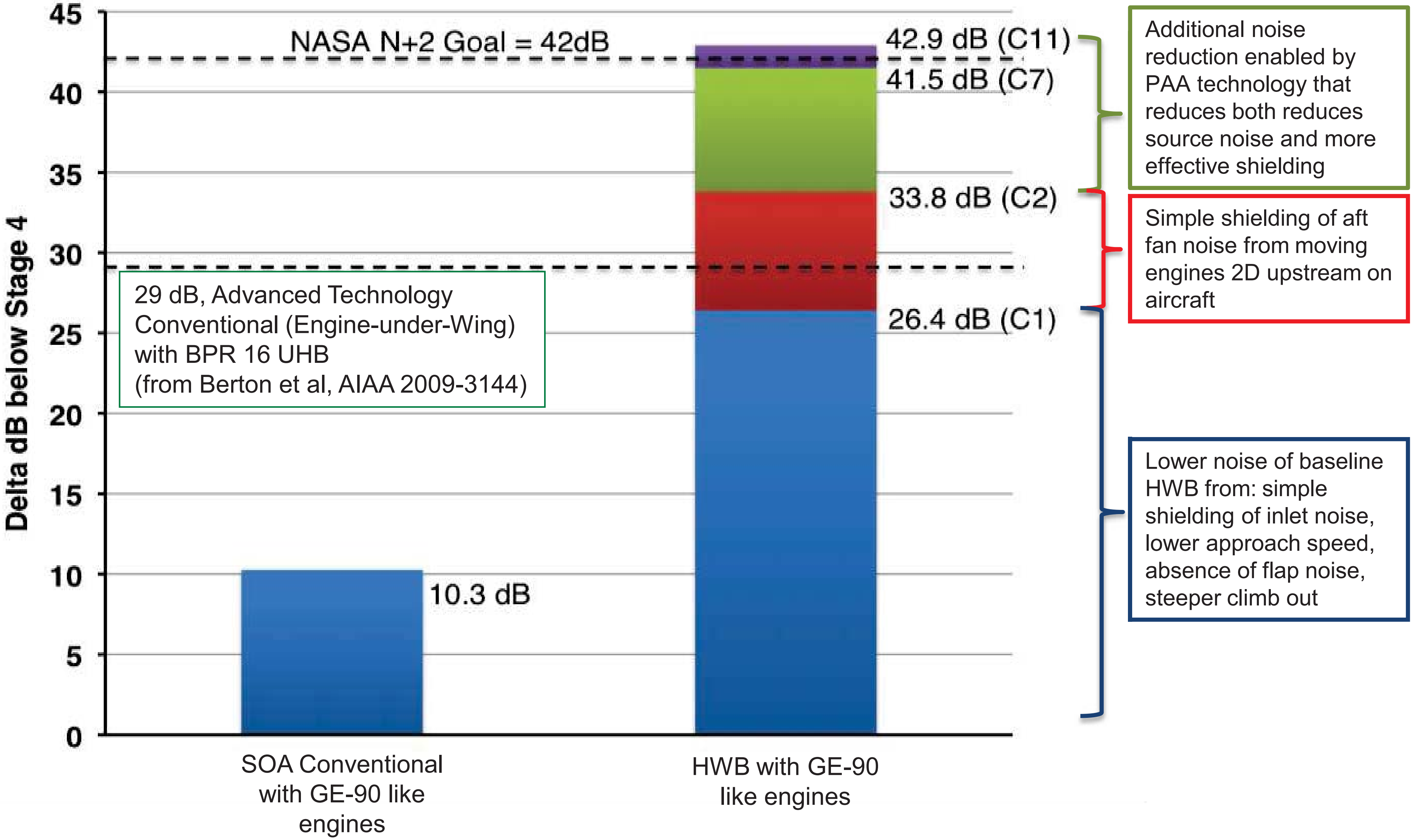
Rizzi, S.A., Aumann, A.R., Lopes, L.V., and Burley, C.L., "Auralization of Hybrid Wing Body Aircraft Flyover Noise from System Noise Predictions," AIAA Paper 2013-0542, January, 2013.


N+2 Concepts

N+3 Concepts

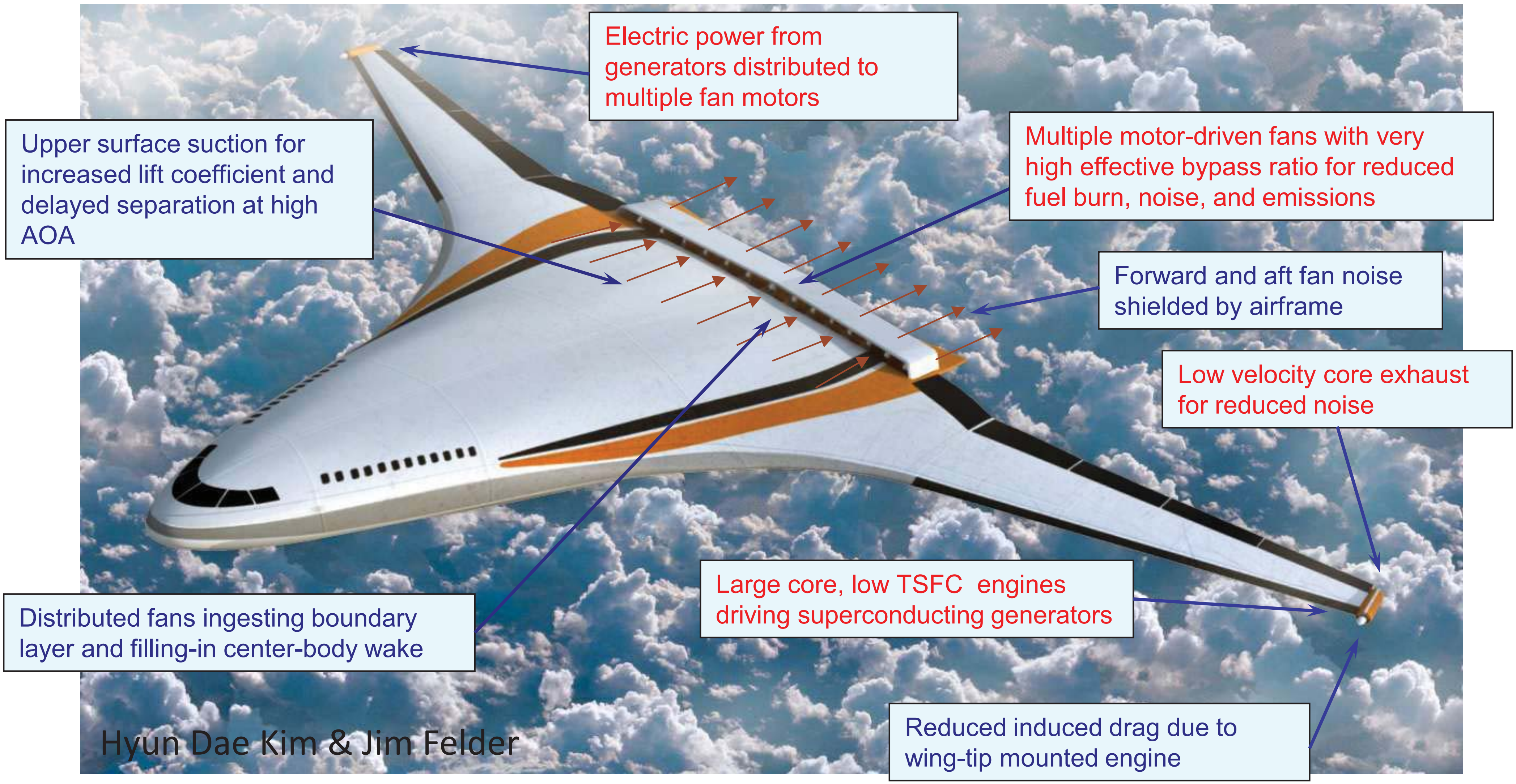


NASA N+2 ERA example: hybrid wing body (Nickol, October 2012)



Thomas, R.H., Burley, C.L, and Olson, E.D., "Hybrid Wing Body Aircraft System Noise Assessment with Propulsion Aircraft Aeroacoustic Experiments," *International Journal of Aeroacoustics*, Vol 11 (3+4), pp.369-410, 2012.

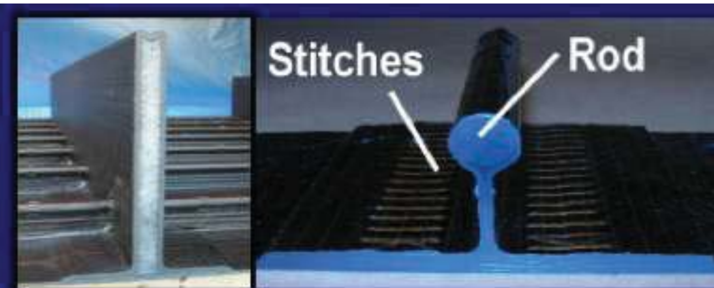
NASA Turboelectric Distributed Propulsion N3X



Hybrid Wing Body

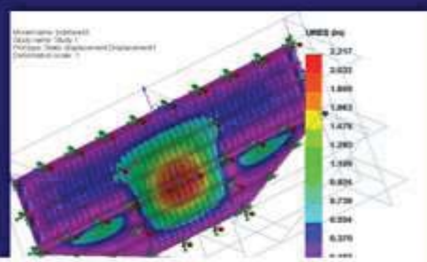
Unitized Stitched Composite Structures

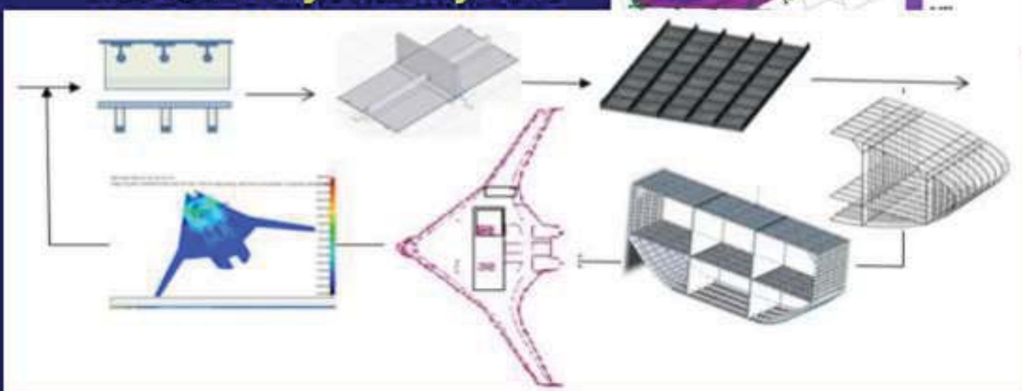
- Not "black aluminum"
- "Fail-safe" damage tolerance
- Load tailoring and weight estimation tools
  - Integrate alternate technologies (cabin noise, etc.)
- Expect 10% weight reduction compared to conventional composites
- Easier tooling

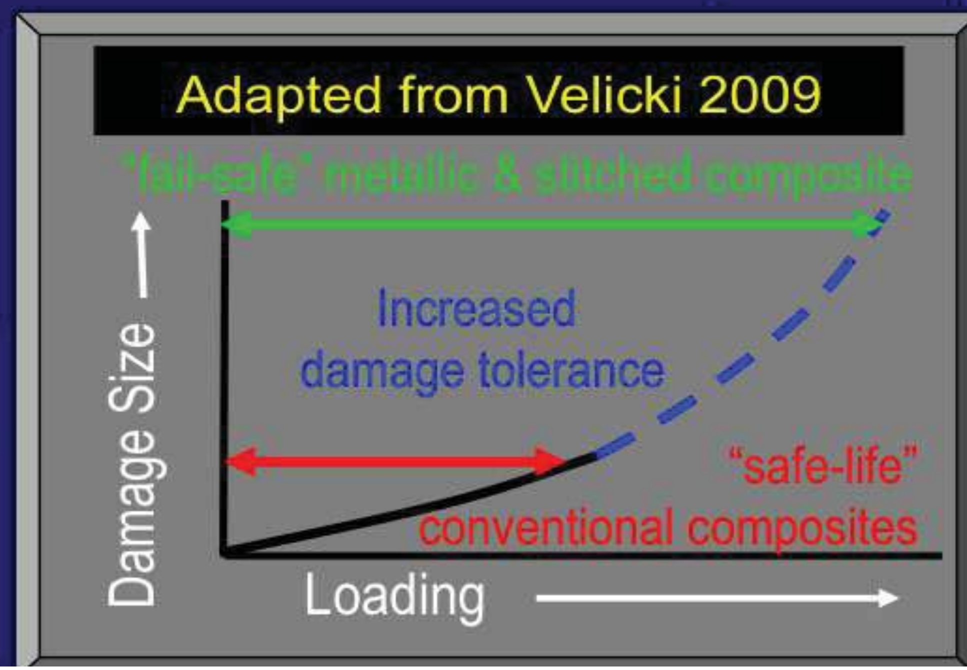


Pultruded Rod Stitched Efficient Unitized Structure (PRSEUS)

PRSEUS Multi-bay Analysis



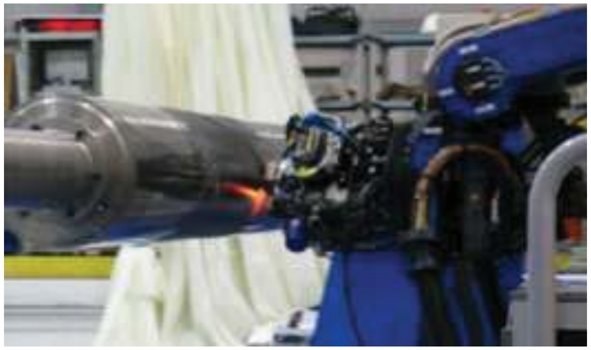




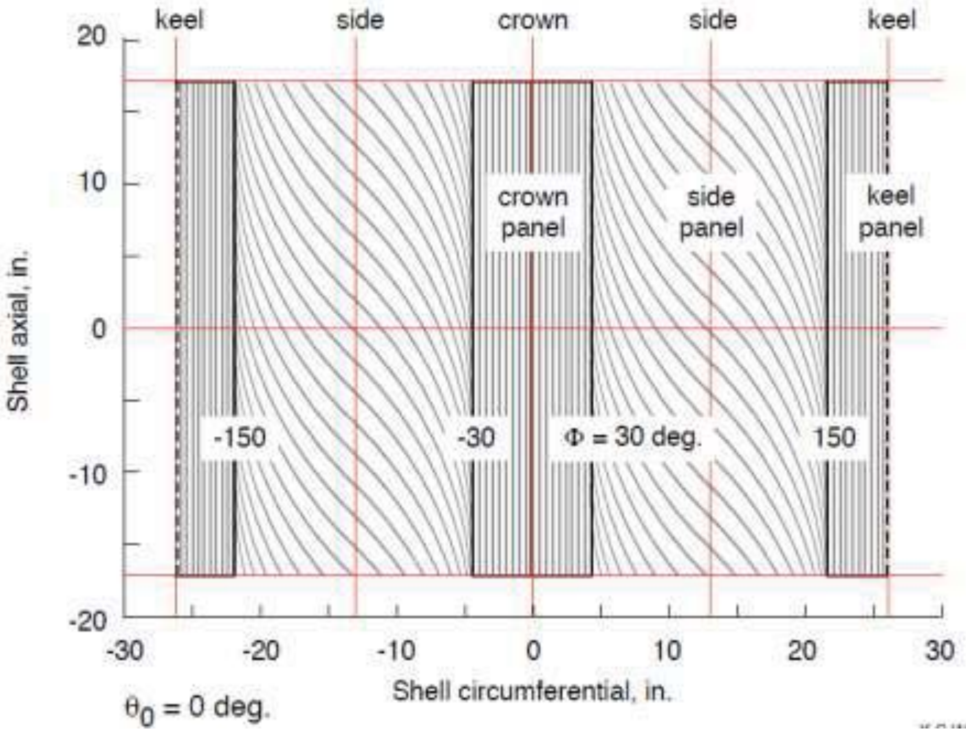
Highly Tailored Composite Structures

Tow-Steered CFRP

- Fiber winding and automatic tape placement are industry standards
- Fiber tow steering places individual fiber tows, enabling tighter radii curves and control of fiber distribution
- Fiber tow steering equipment exists, but design and analysis tools to effectively tailor localized laminate properties are lacking
- ***Develop analysis and design tools to optimize structures through tailored placement of fibers within composite***

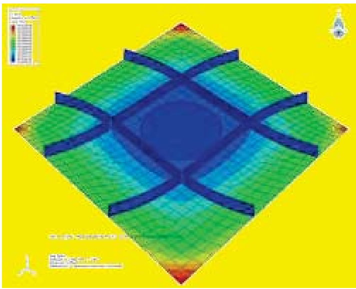


Fabrication at NCAM/MAF



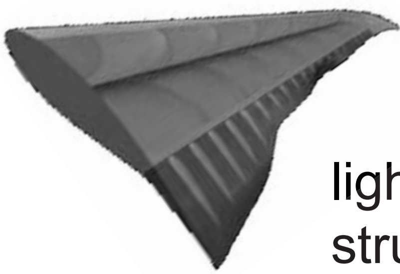
Weight Reduction and Manufacturing

tailored metallic structures via electron beam free form fabrication (EBF3)



structural design optimization with curvilinear stiffeners

fabrication & testing of structural designs

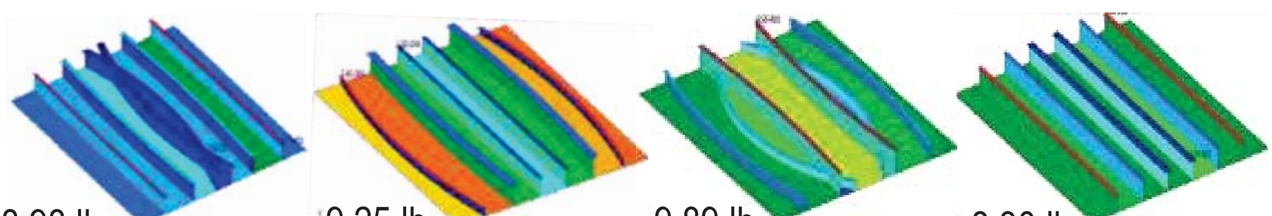


lightweight aeroelastically tailored wing structure with integral control surfaces

T-stiffened panel designed and optimized using EBF3PanelOpt, in compression test system

EBF3PanelOpt

Design Candidates Using Several Variations of Geometry Input Parameters

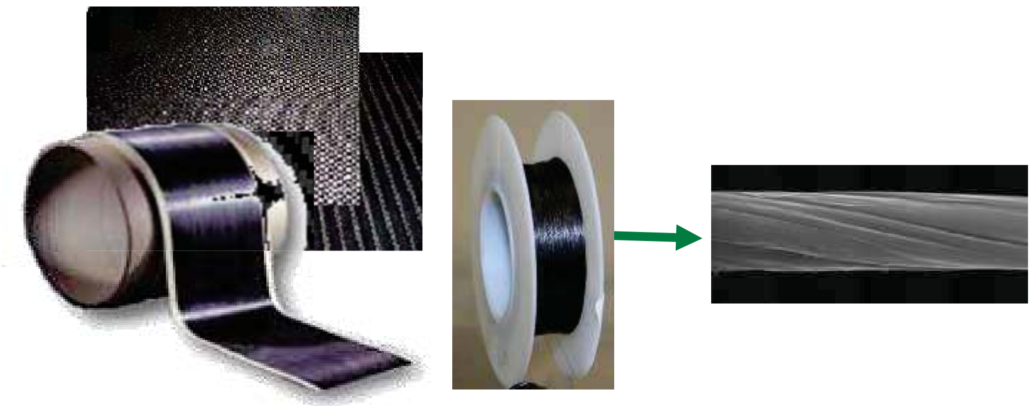


8.98 lb 9.25 lb 9.89 lb 8.30 lb

Virginia Tech, Lockheed Martin, NASA

Weight Reduction via Advanced Multifunctional and Tailored Materials

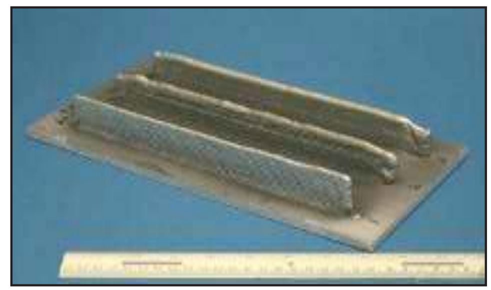
Variable Stiffness
Hybrid CNT CFRP/ All CNT



CNT Tapes and Yarns - *Nanocomp Technologies*

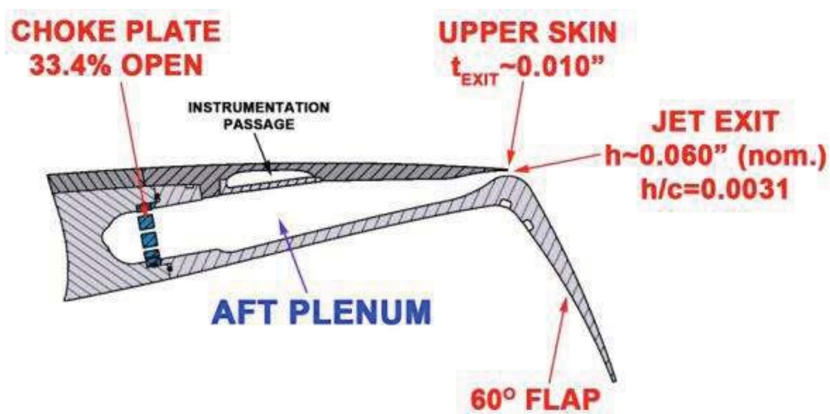
nano-structured elements within active polymeric materials for active wing skin (load bearing + electric conductivity)

Designer Metallics
Functionally Graded Metal Alloys

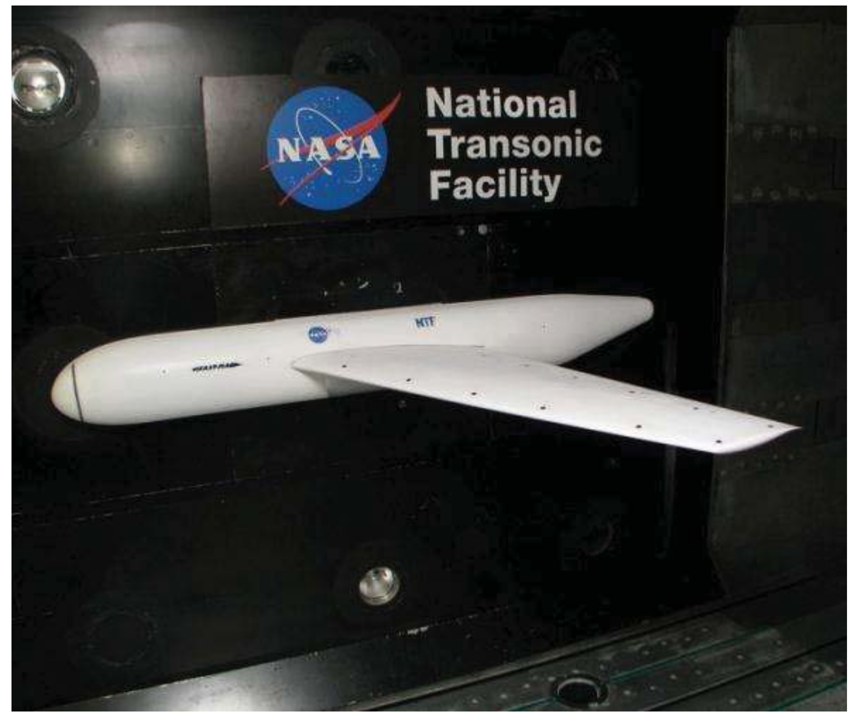


tailored metal alloys
vary material properties continuously throughout a structure

Circulation Control Research – High Rn

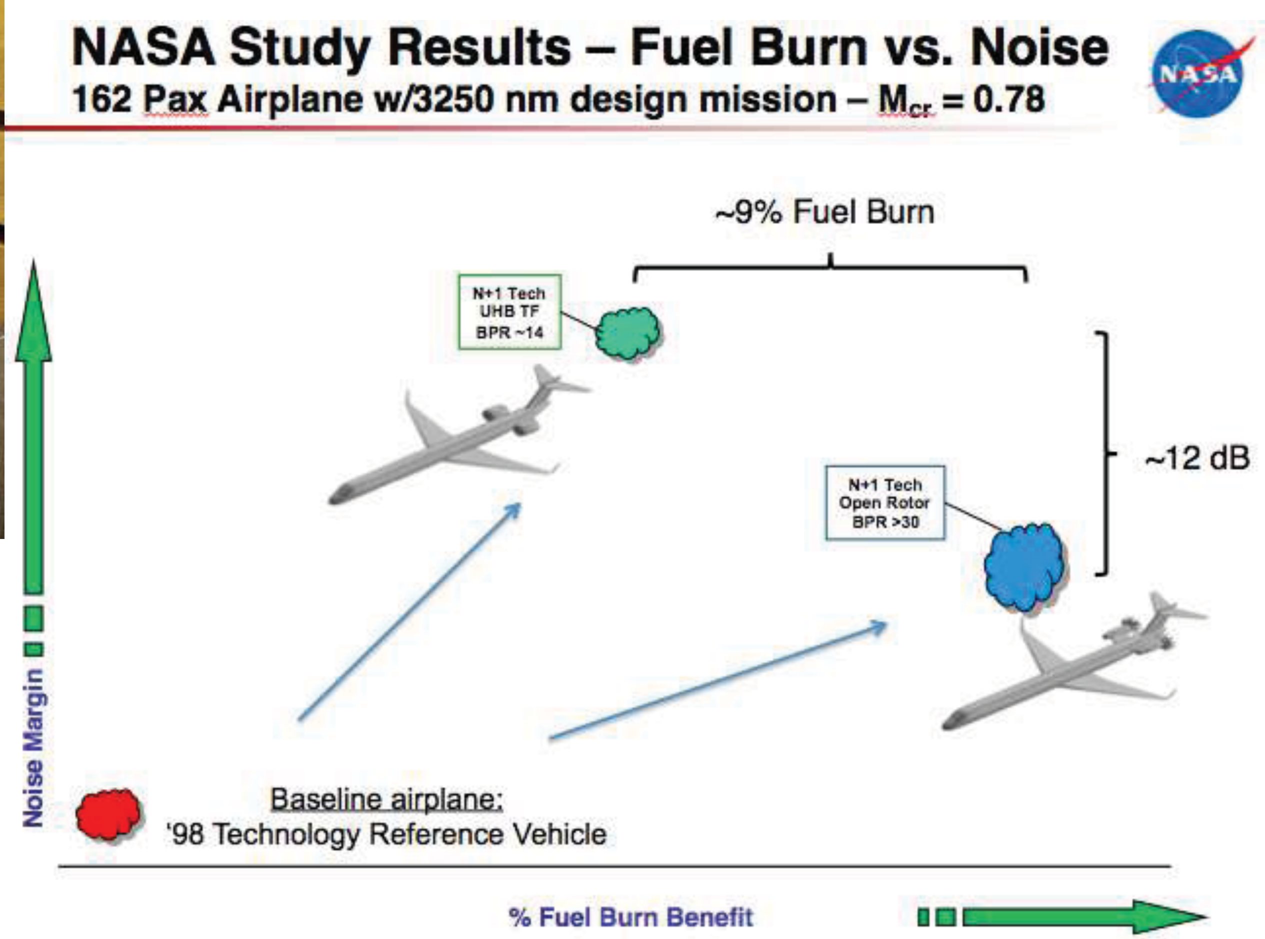


FAST-MAC

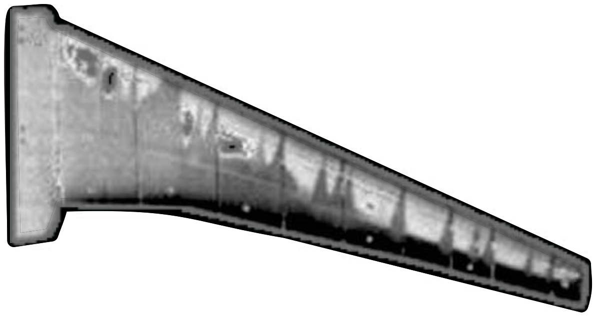


Fundamental Aerodynamics Subsonic/Transonic-Modular Active Control

Ultra high BPR engines



DRAG REDUCTION – Via Flow Control

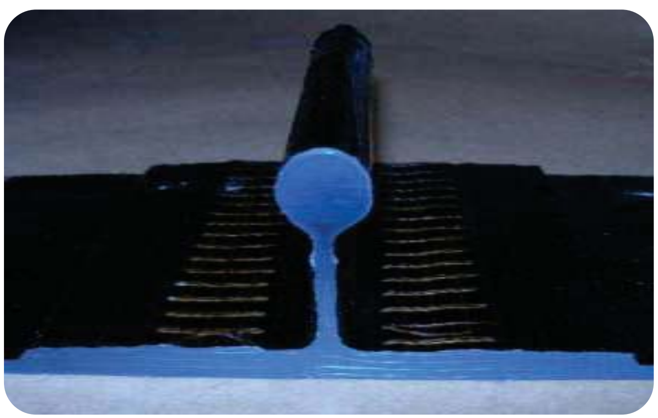


SFC/NOISE REDUCTION

Advanced Cores and Development of
Integration of Advanced UHB Engines

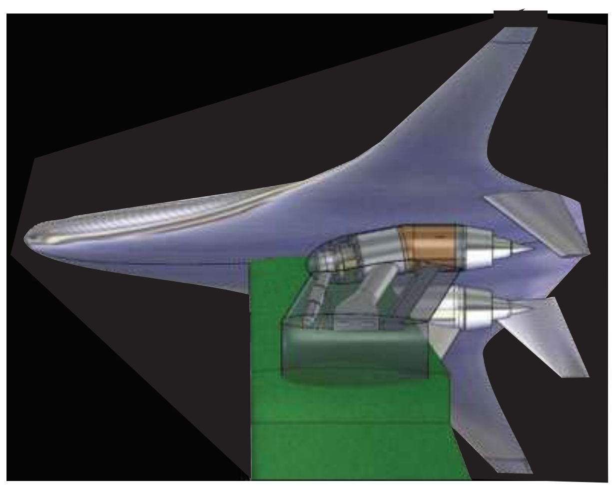
WEIGHT REDUCTION

PRSEUS – Pultruded Rod Stitched Efficient
Unitized Structure



PROPULSION NOISE
Fan, Core and Jet Noise

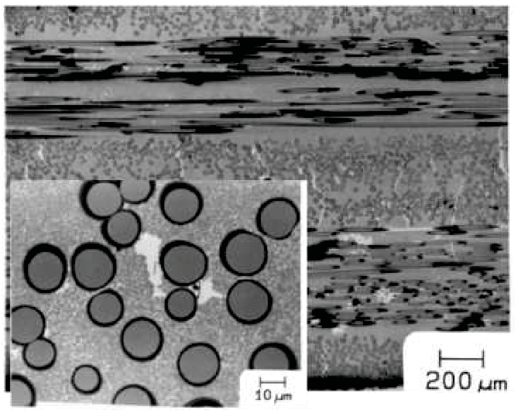
AIRFRAME NOISE
High-lift Systems and
Landing Gear



PROPULSION
AIRFRAME
AEROACOUSTICS

Airframe/Propulsion
Interaction & Shielding

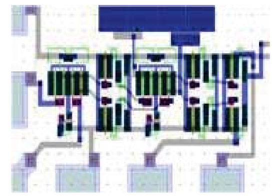
CMC COMBUSTOR LINER
For higher engine temps



SIC CMC Concepts

CMC combustor liner

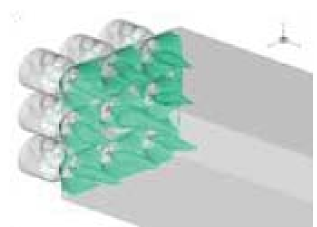
INSTABILITY CONTROL
Suppress combustor instabilities



High Temperature SiC electronics circuits and dynamic pressure sensors

Fuel Modulation for high frequency fuel delivery systems

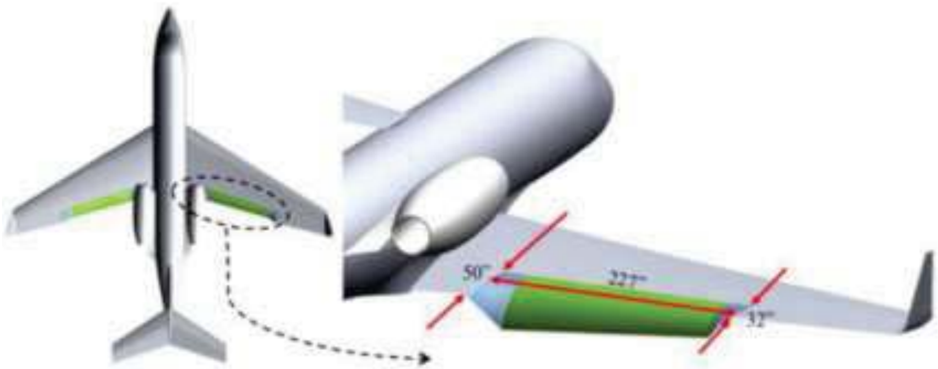
LOW NOX, FUEL FLEXIBLE DESIGN/TEST

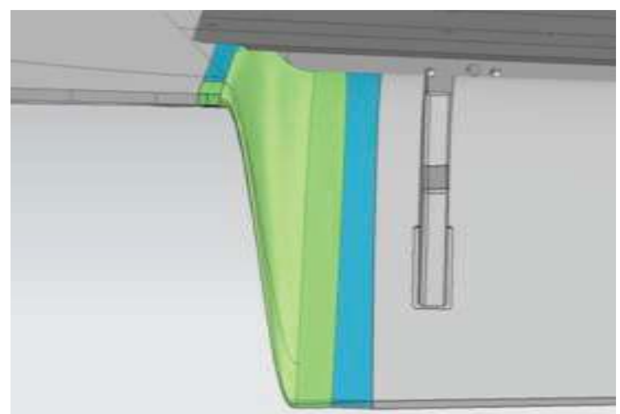


Innovative Injector Concept

ASCR Combustion Rig

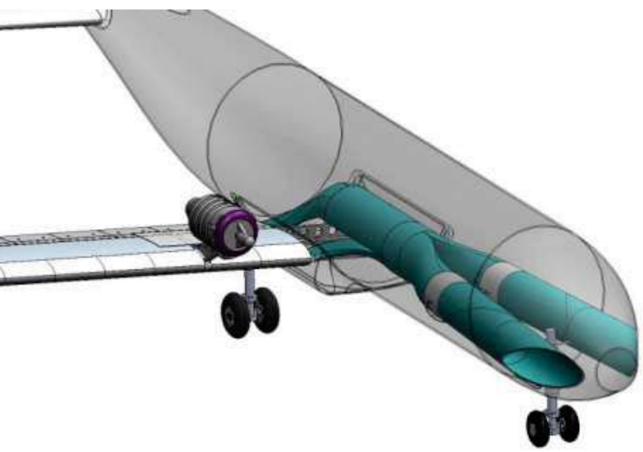
Elastomers – Noise Mitigation & Aero Efficiency





Prototype Technology Evaluation Research Aircraft (PTERA)

AREA-I

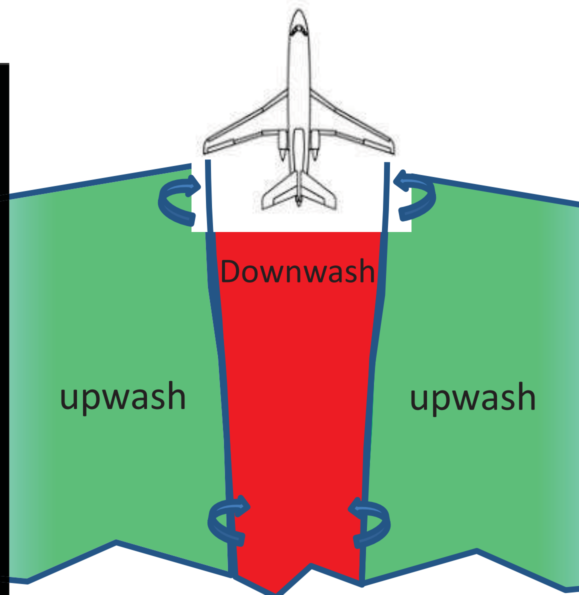


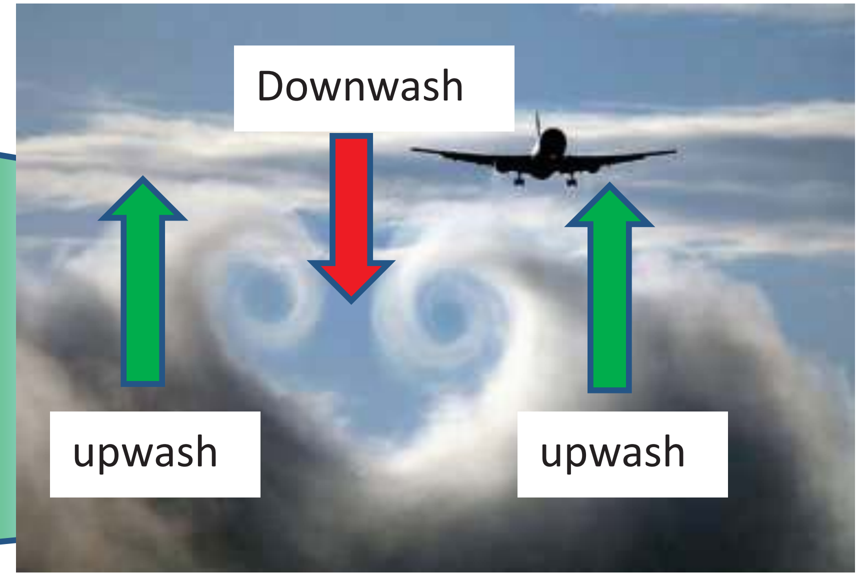
X-56A Multi-Utility Technology Testbed (MUTT)

- Develop robustness criteria for active structural control
- Integrate emerging sensor technology (i.e. FOSS, LESP)
- Use MDAO and flight measurements to improve aeroservoelastic modeling and analysis
- Publish and distribute open source flight-validated realistic aeroelastic models for academia and industry use
- Develop future research experiments (i.e. distributed conformal trailing edge flap control)

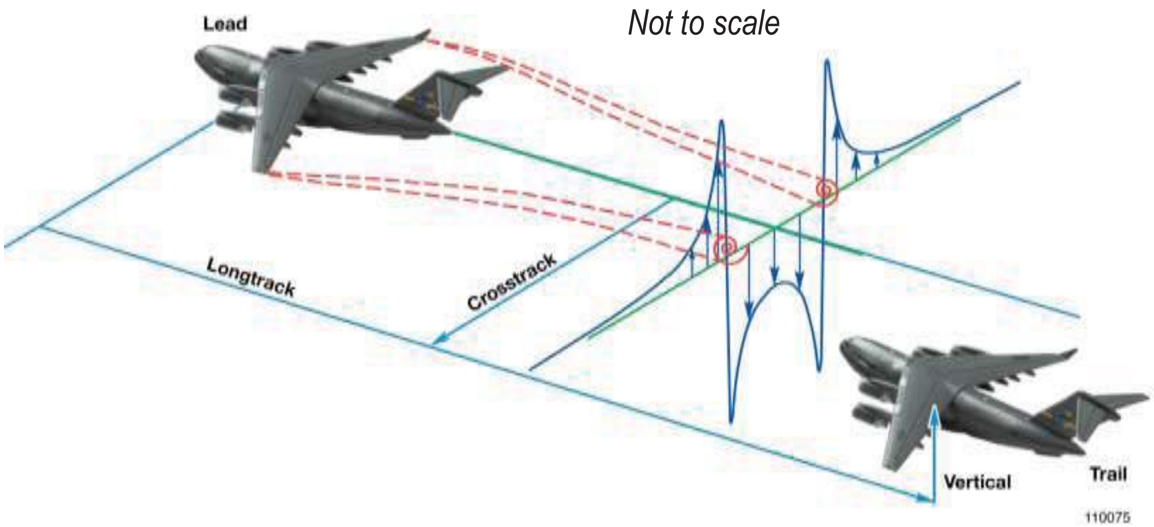
Quiet Supersonic

Formation Flight





C-17 in Formation Flight



Approximately to scale

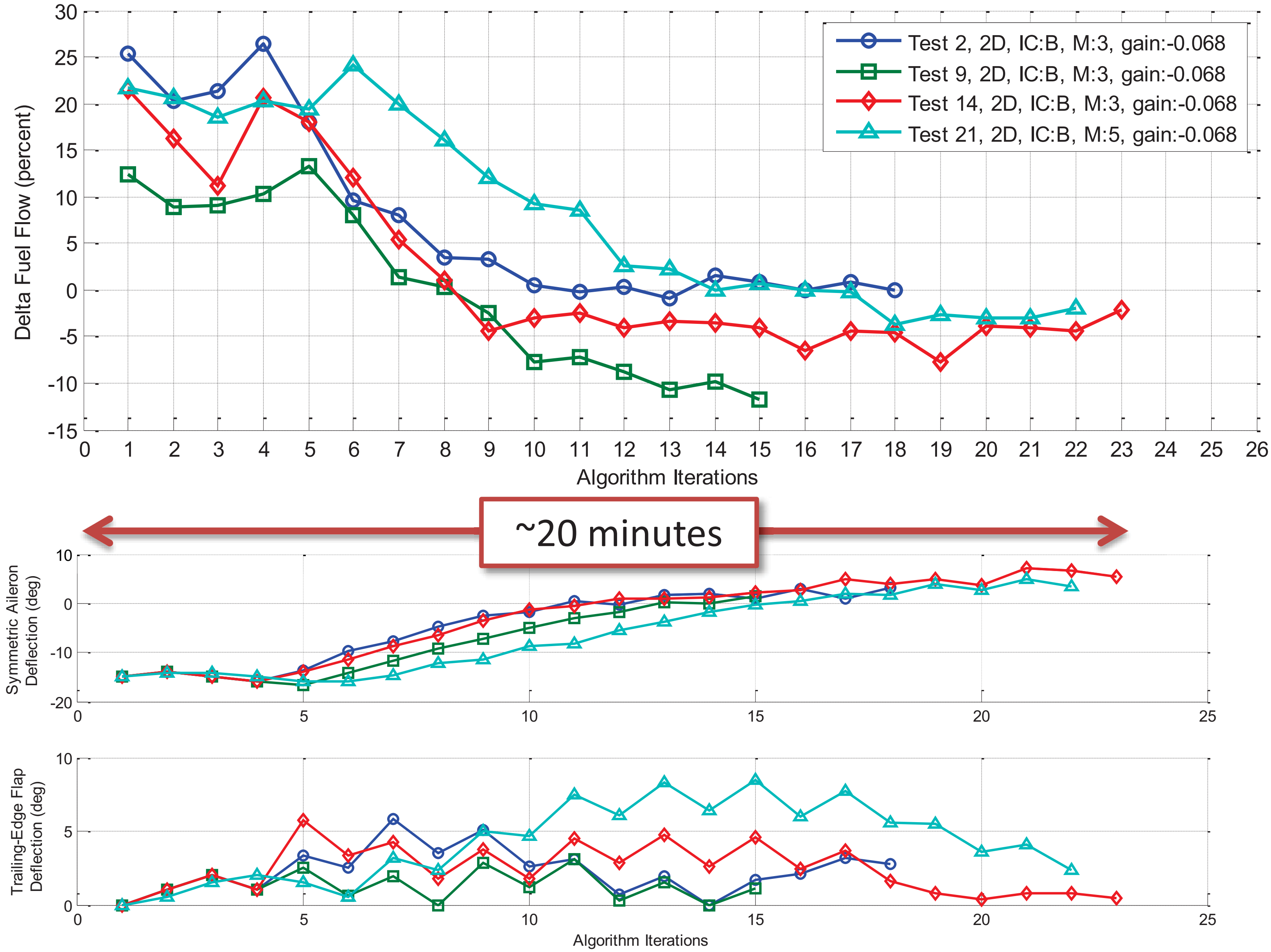
Pahle, et al. “An Initial Flight Investigation of Formation Flight for Drag Reduction on the C-17 Aircraft” AIAA Atmospheric Flight Mechanics Conference, August 2012. AIAA 2012-4802

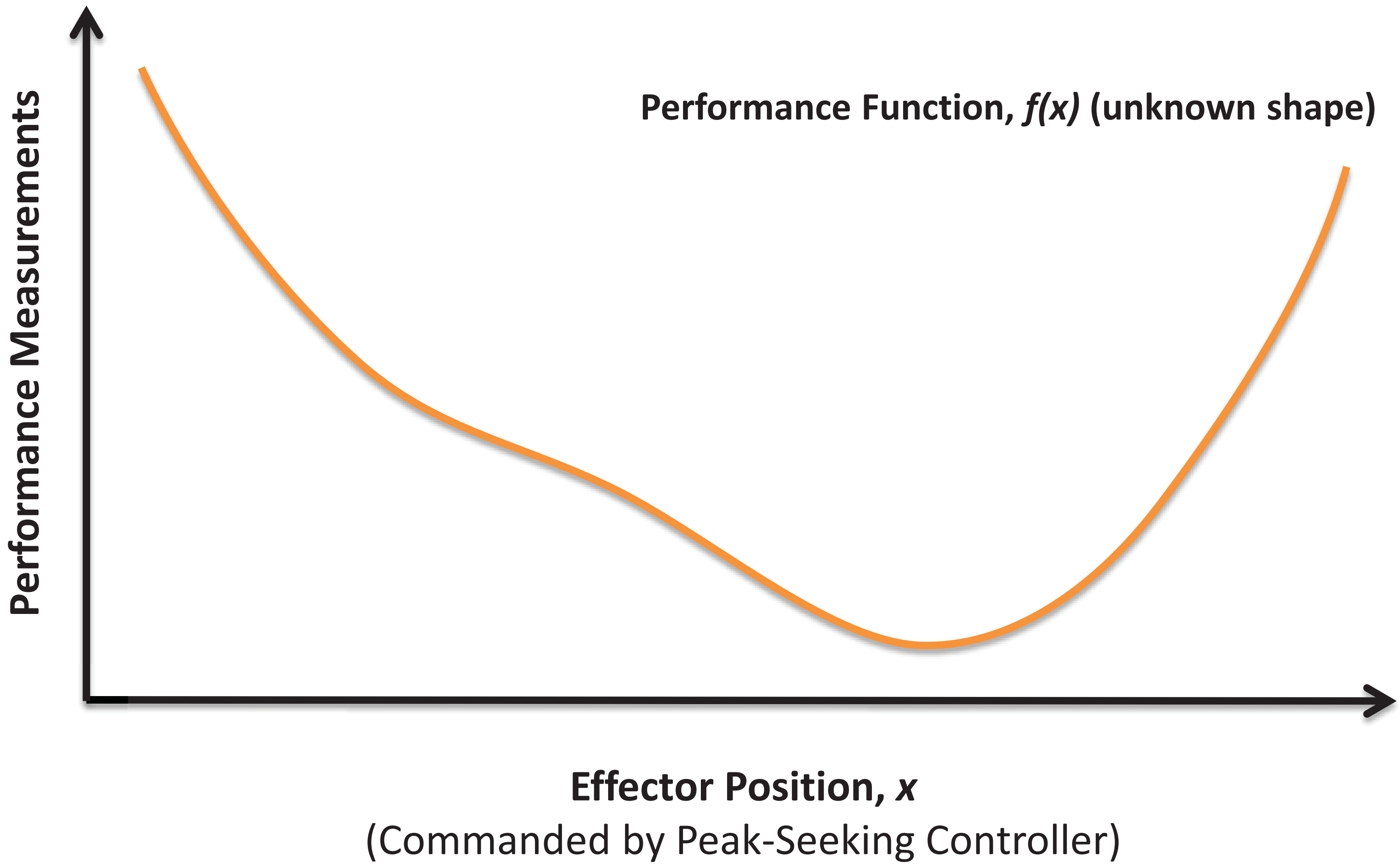
Peak-seeking control: Typical flight results

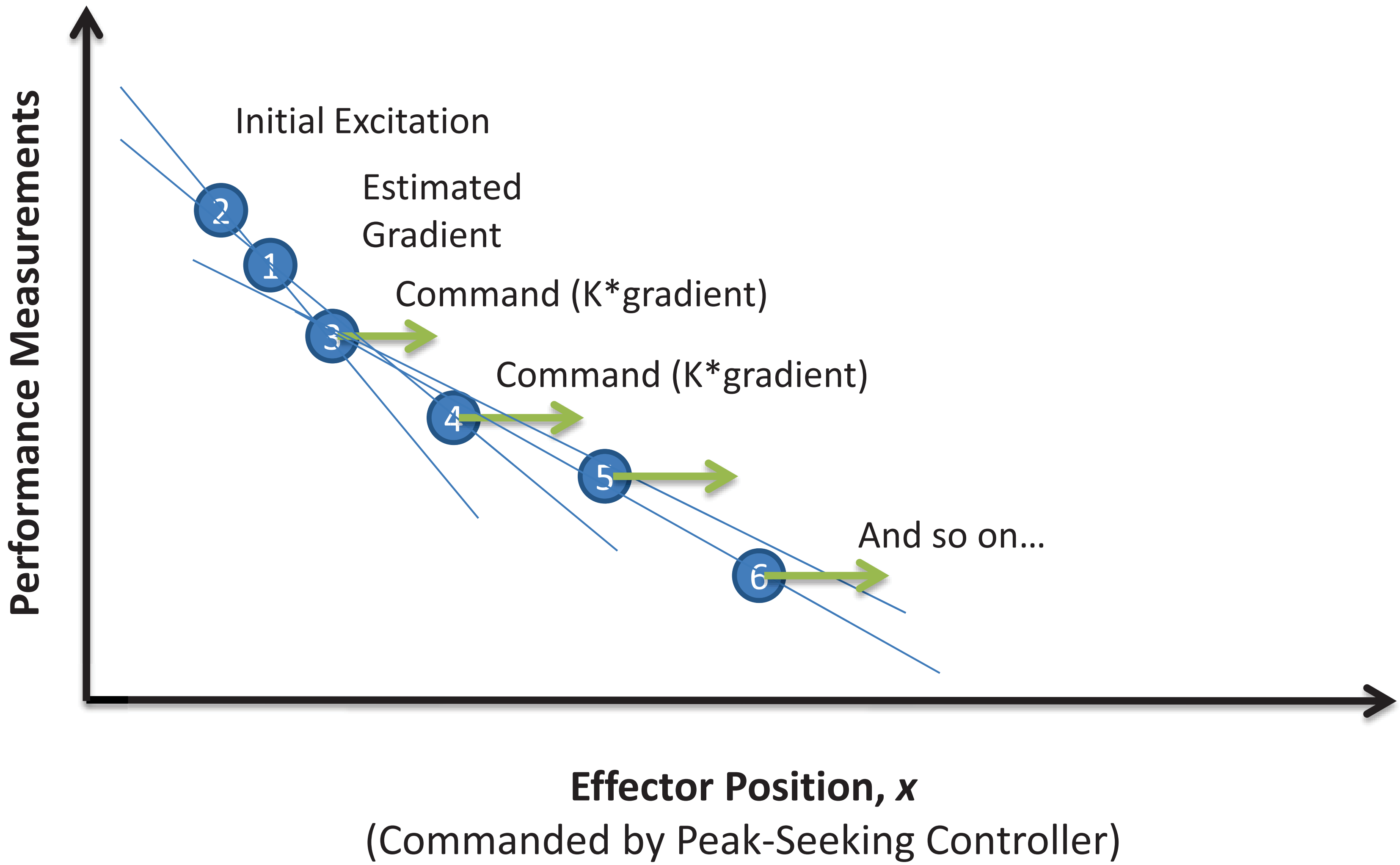
Fuel Flow

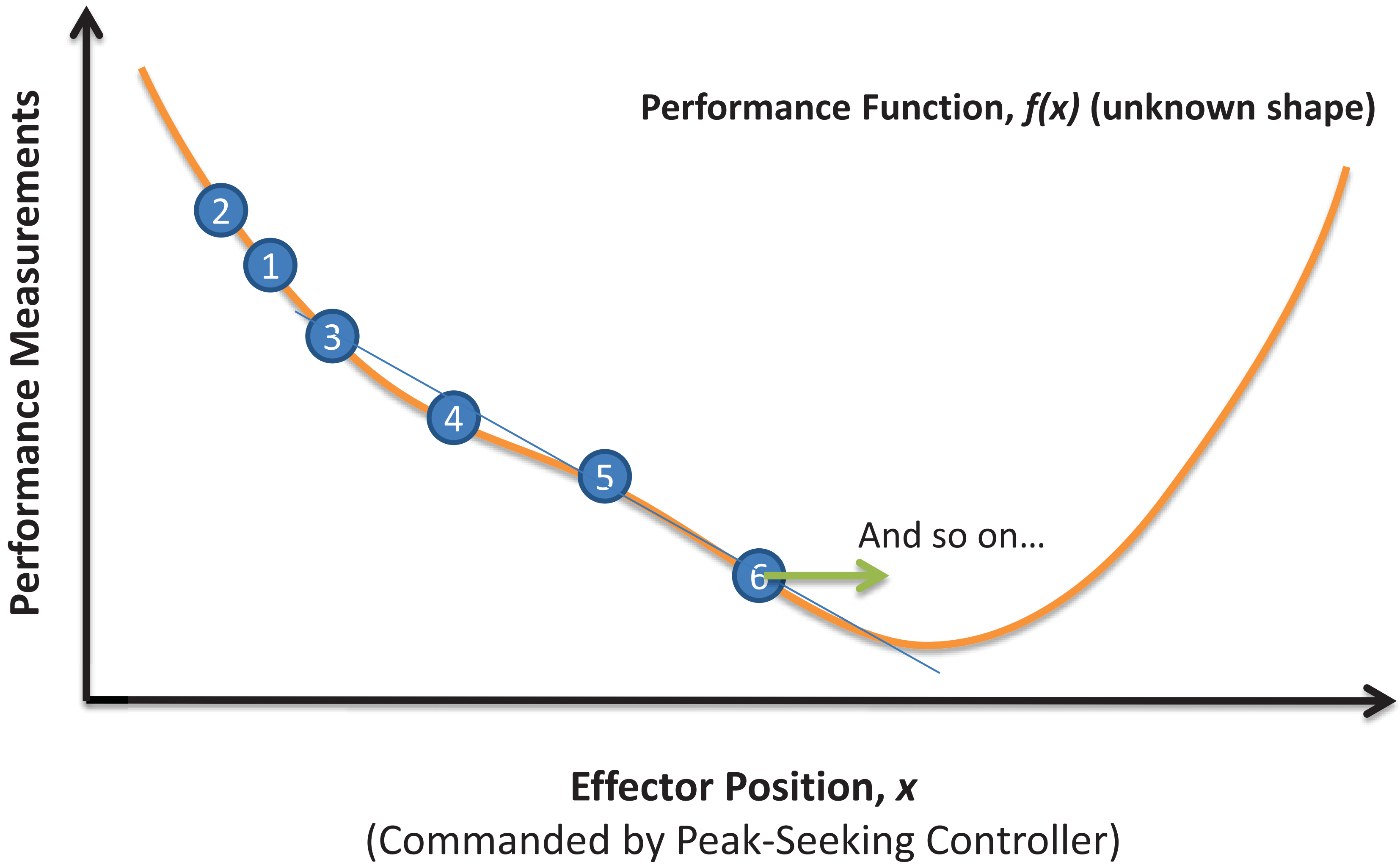
Ailerons (+TED)

Flaps (+TED)

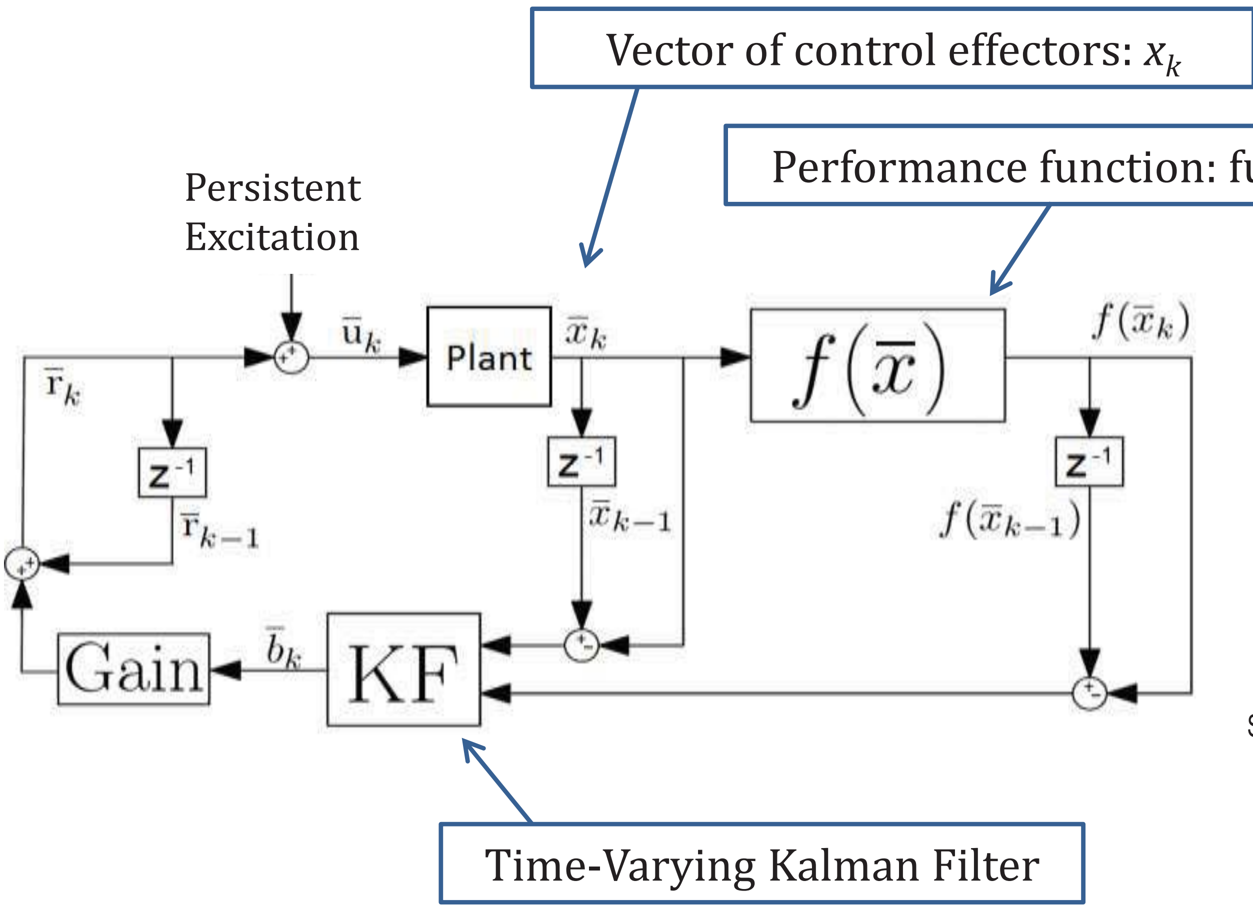


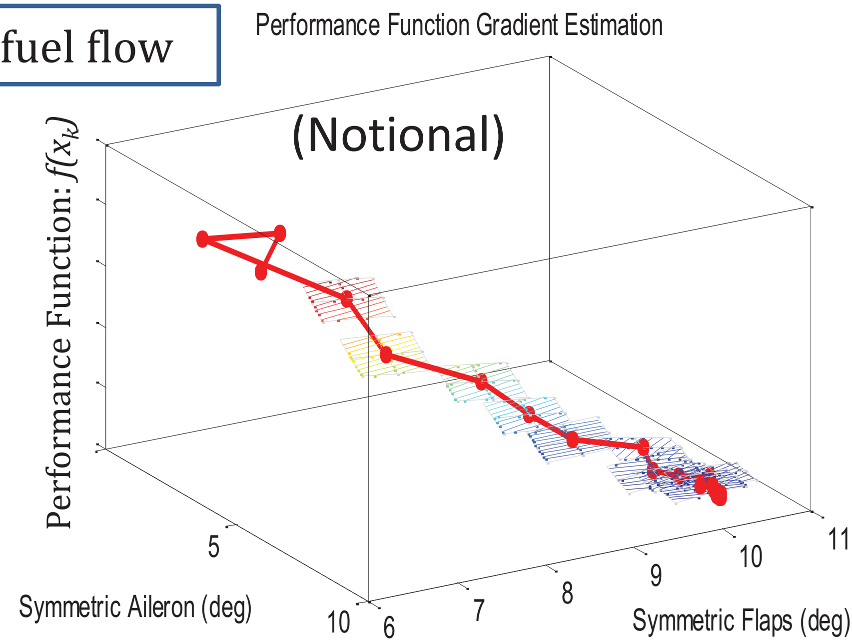

Performance Measurements
Performance Function, *f(x)* (unknown shape)
Effector Position, *x*
(Commanded by Peak-Seeking Controller)


Performance Measurements
Initial Excitation
Estimated
Gradient
Command (K*gradient)
Command (K*gradient)
And so on...
2
1
3
4
5
6
Effector Position, x
(Commanded by Peak-Seeking Controller)



Performance Measurements
Performance Function, *f(x)* (unknown shape)
2
1
3
4
5
6
And so on...
Effector Position, *x*
(Commanded by Peak-Seeking Controller)



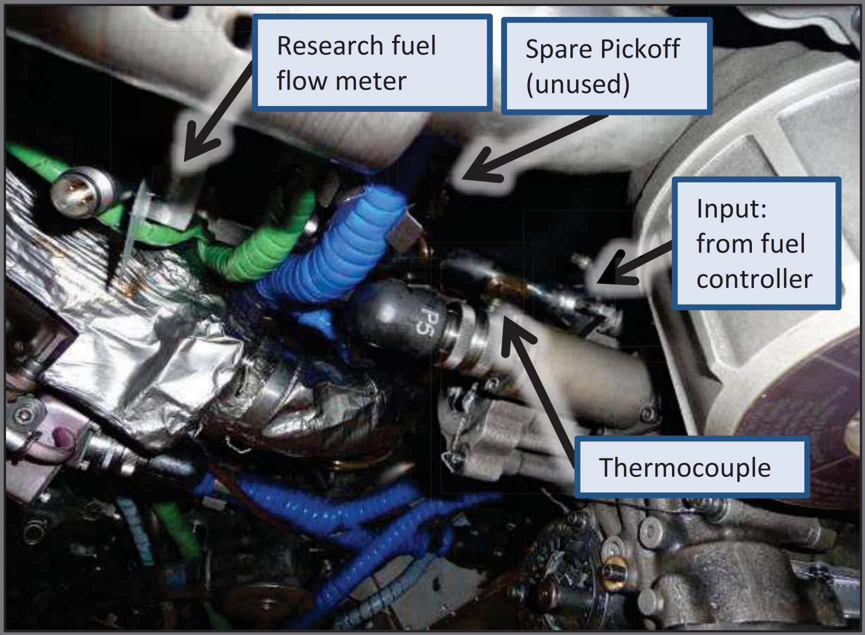


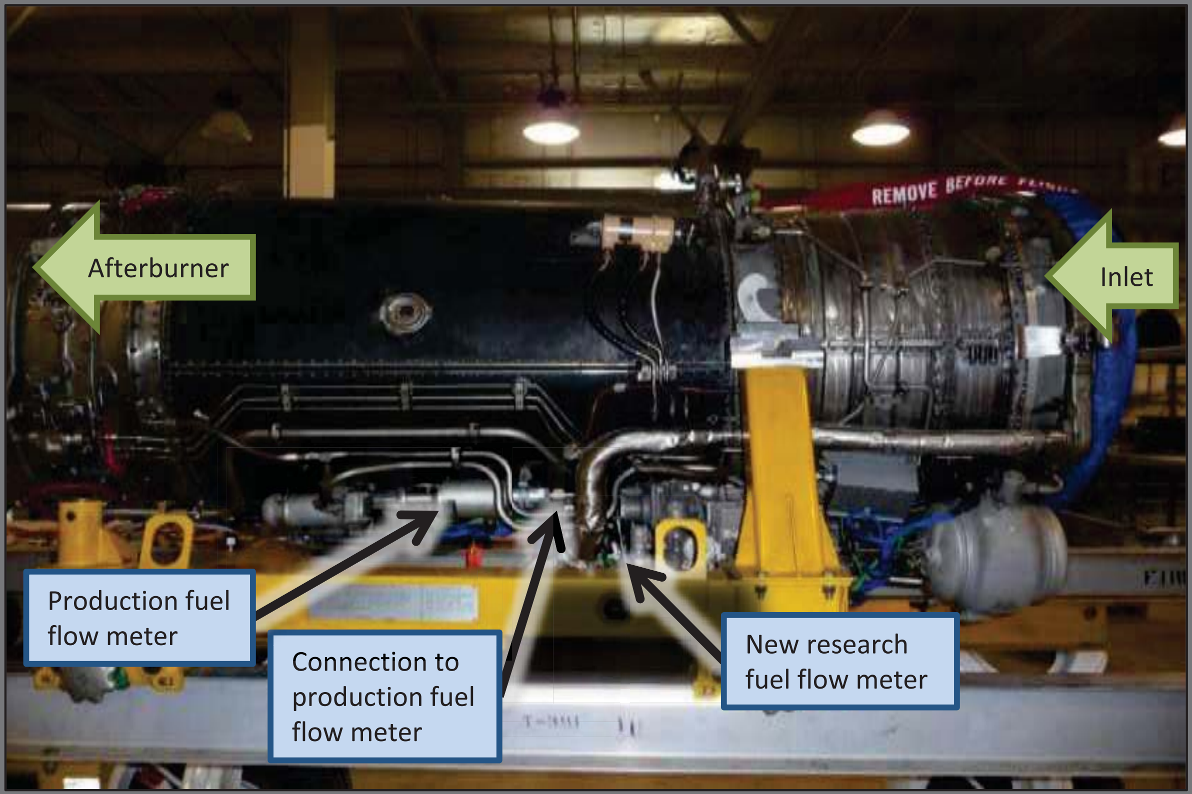
Approach based on work by Ryan and Speyer:

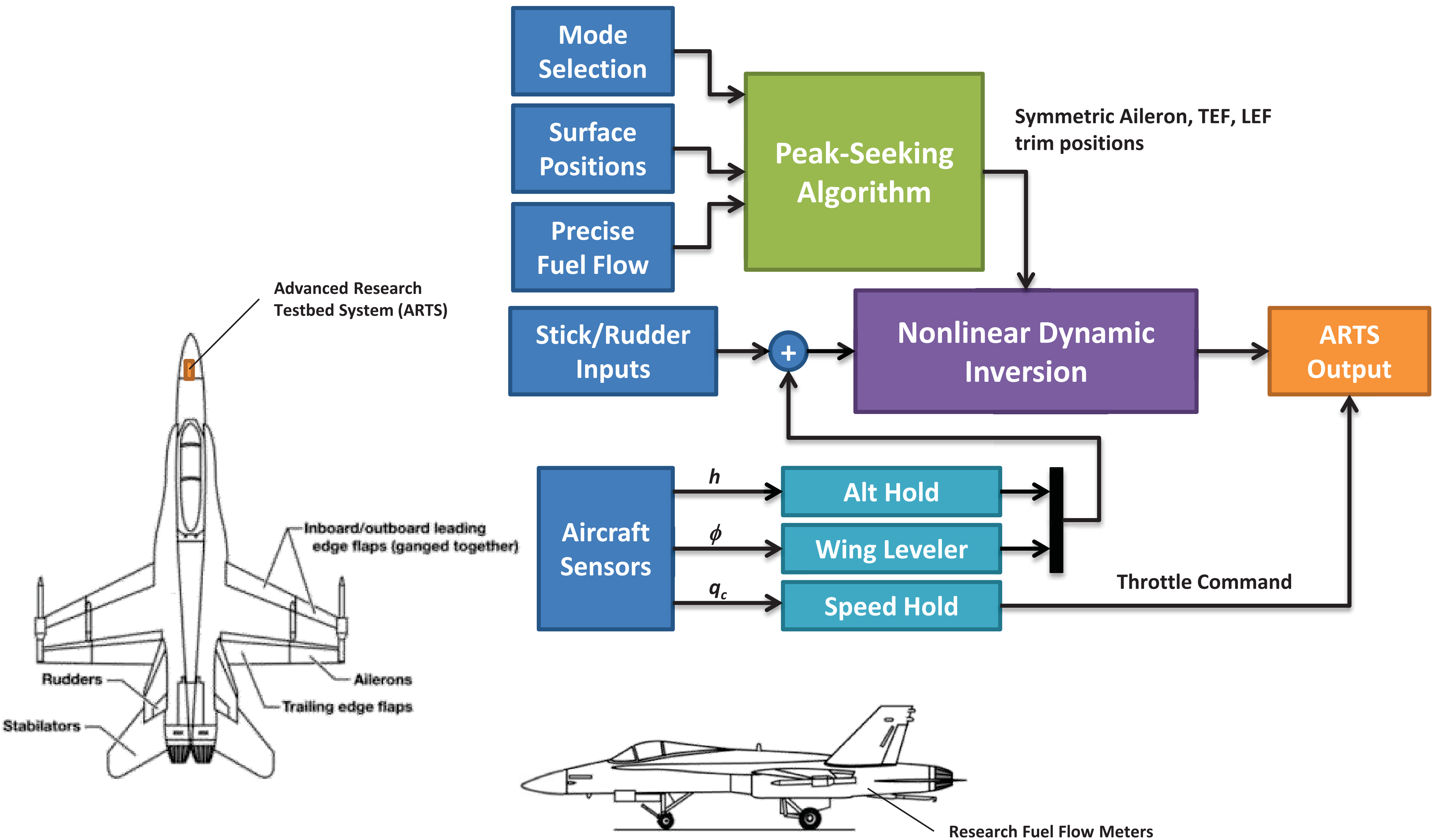
Ryan, J.J. and Speyer, J.L., “Peak-Seeking Control Using Gradient and Hessian Estimates” Proceedings of the 2010 American Control Conference, June 30-July 2, 2010, pp. 611-616.

http://hdl.handle.net/2060/20100024511

NASA
853
Dryden Flight Research Center
NASA
BOEING


Research fuel flow meter
Spare Pickoff (unused)
Input: from fuel controller
Thermocouple

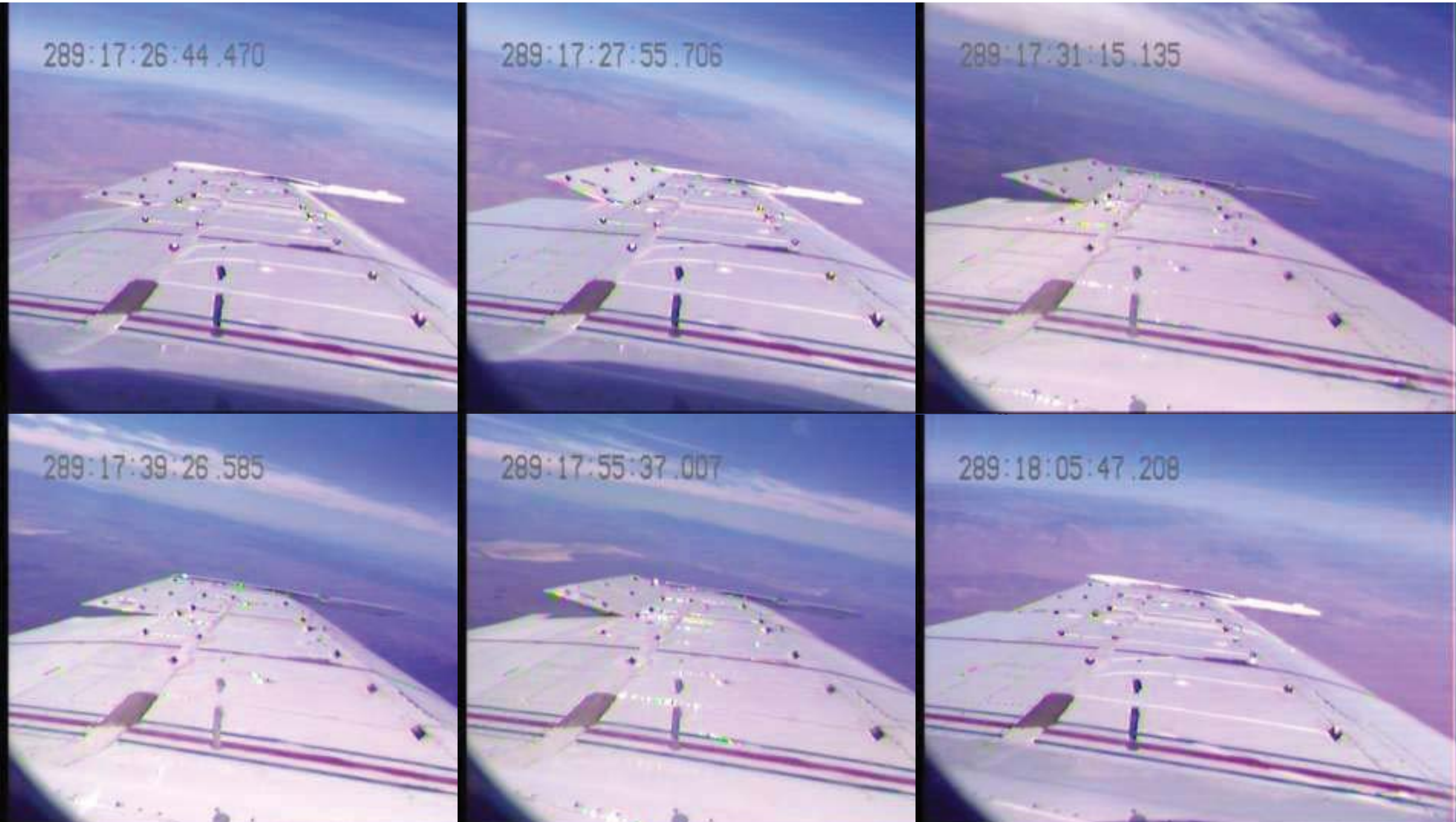

REMOVE BEFORE
Afterburner
Inlet
Production fuel flow meter
Connection to production fuel flow meter
New research fuel flow meter

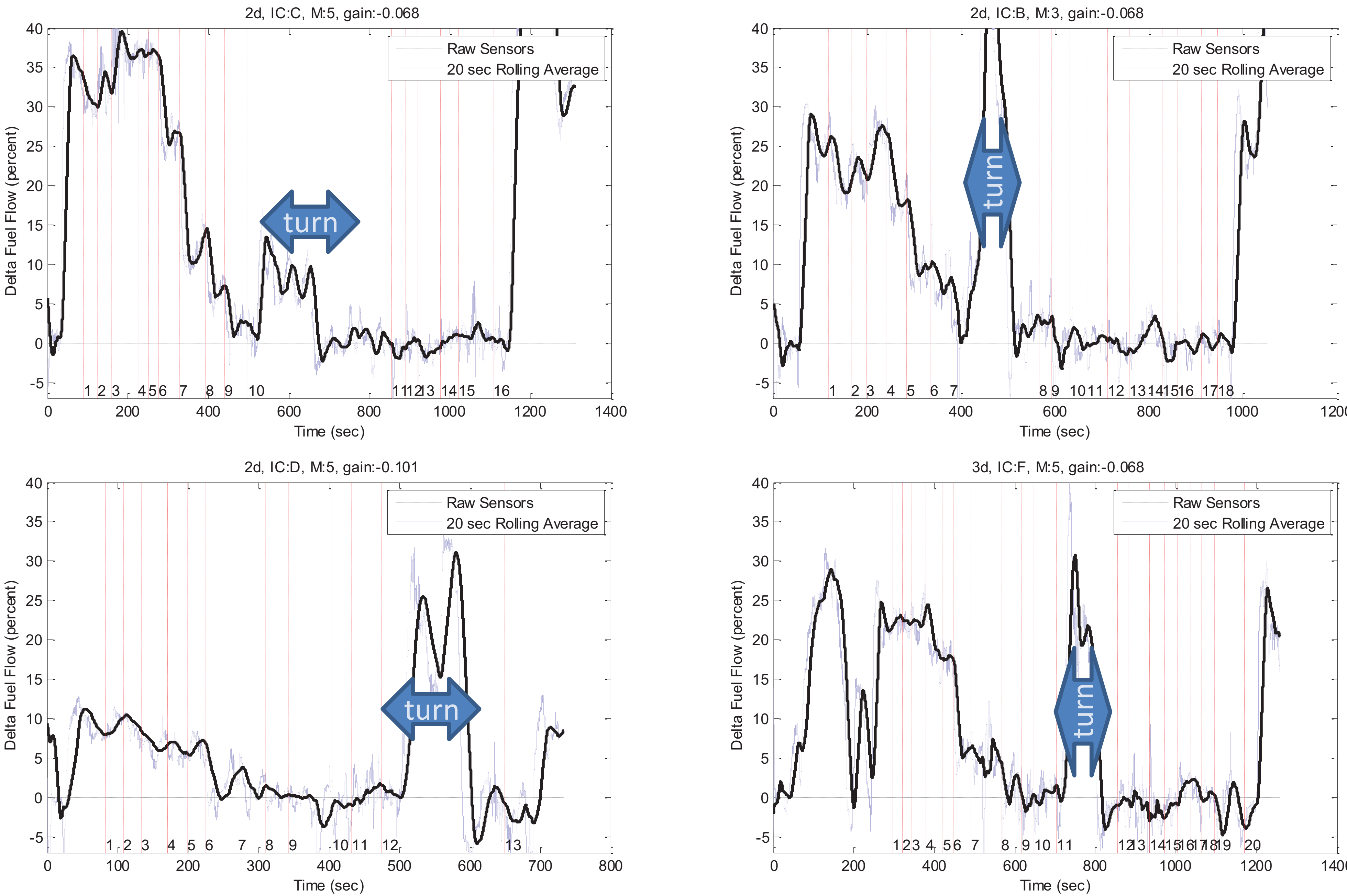

Mode Selection
Surface Positions
Precise Fuel Flow
Peak-Seeking Algorithm
Symmetric Aileron, TEF, LEF trim positions
Advanced Research Testbed System (ARTS)
Stick/Rudder Inputs
+
Nonlinear Dynamic Inversion
ARTS Output
Aircraft Sensors
h
ϕ
q_c
Alt Hold
Wing Leveler
Speed Hold
Throttle Command
Inboard/outboard leading edge flaps (ganged together)
Rudders
Ailerons
Trailing edge flaps
Stabilators
Research Fuel Flow Meters

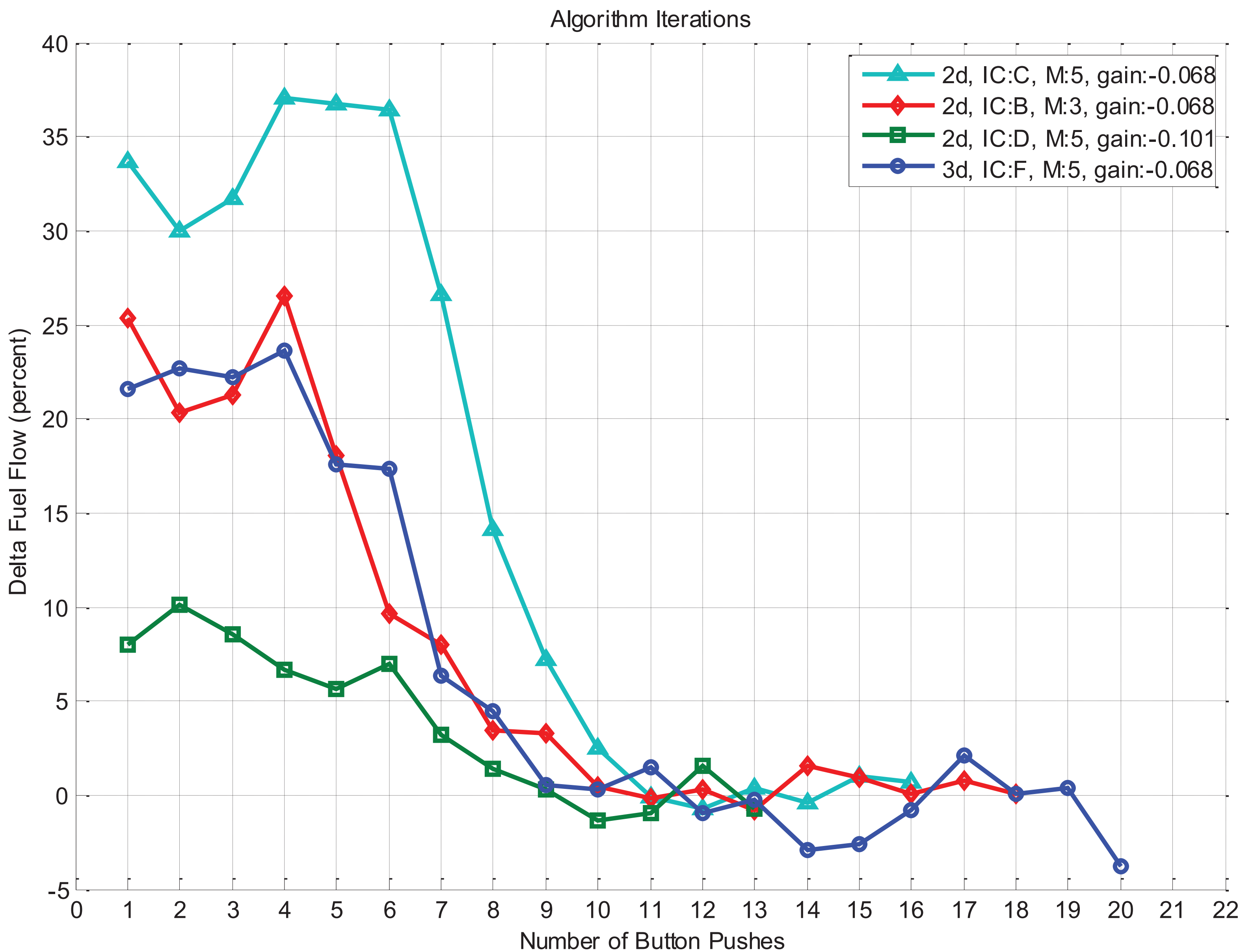

DANGER
Center
JIM "CLUE" LESS
NILS LARSON
DANGER
EJECTION
SEAT
DANGER
DANGER


NASA
NASA

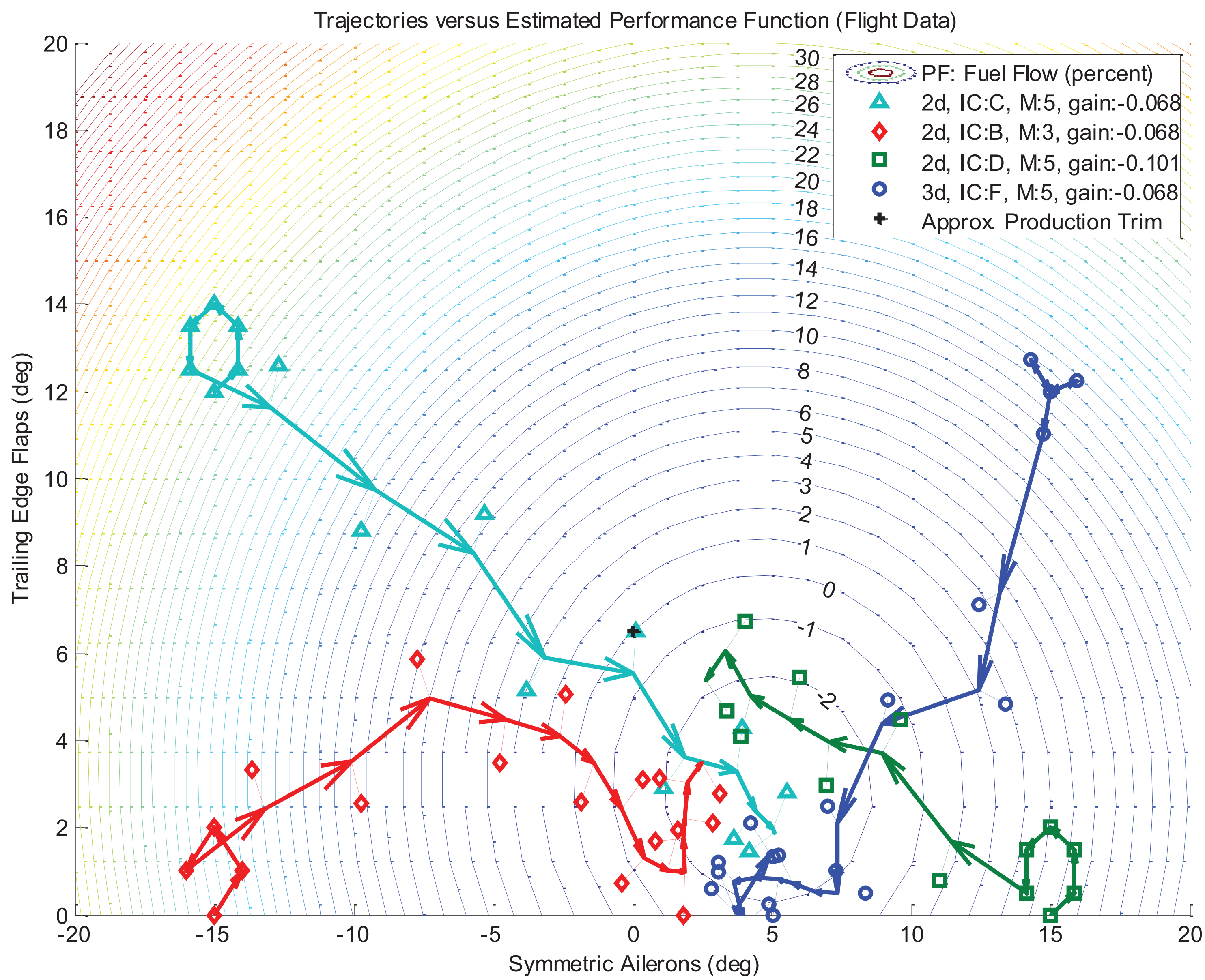

NASA
IADS


289:17:26:44.470
289:17:27:55.706
289:17:31:15.135
289:17:39:26.585
289:17:55:37.007
289:18:05:47.208


2d, IC:C, M:5, gain:-0.068
Raw Sensors
20 sec Rolling Average
turn
Delta Fuel Flow (percent)
Time (sec)
2d, IC:B, M:3, gain:-0.068
Raw Sensors
20 sec Rolling Average
turn
Delta Fuel Flow (percent)
Time (sec)
2d, IC:D, M:5, gain:-0.101
Raw Sensors
20 sec Rolling Average
turn
Delta Fuel Flow (percent)
Time (sec)
3d, IC:F, M:5, gain:-0.068
Raw Sensors
20 sec Rolling Average
turn
Delta Fuel Flow (percent)
Time (sec)



Algorithm Iterations
2d, IC:C, M:5, gain:-0.068
2d, IC:B, M:3, gain:-0.068
2d, IC:D, M:5, gain:-0.101
3d, IC:F, M:5, gain:-0.068
Delta Fuel Flow (percent)
Number of Button Pushes
40
35
30
25
20
15
10
5
0
-5
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22



Trajectories versus Estimated Performance Function (Flight Data)
PF: Fuel Flow (percent)
2d, IC:C, M:5, gain:-0.068
2d, IC:B, M:3, gain:-0.068
2d, IC:D, M:5, gain:-0.101
3d, IC:F, M:5, gain:-0.068
Approx. Production Trim
Trailing Edge Flaps (deg)
Symmetric Ailerons (deg)